Fracture Network Assessment of Unconventional Reservoir Production and Enhanced Geothermal Systems

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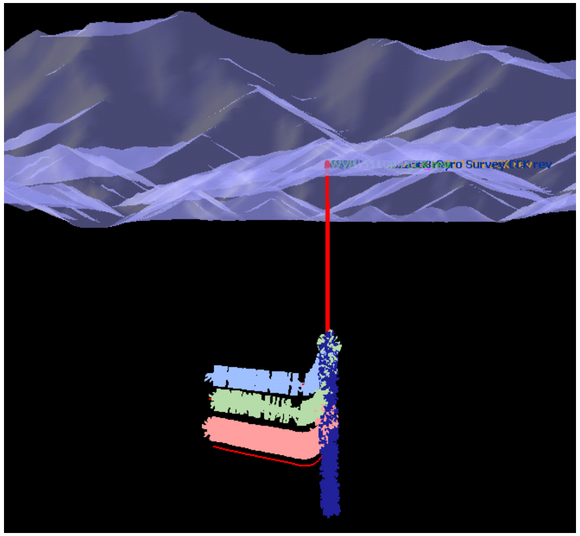
Redmond WA


Gilsonite Dike, Uinta Basin, NE Utah


To Routes 45, 40, and Vernal
Fantasy Canyon
To Ouray
Glen Bench Road
Watson Road
White River
Red Wash
N
0 1
Mile
UTAH

Topics

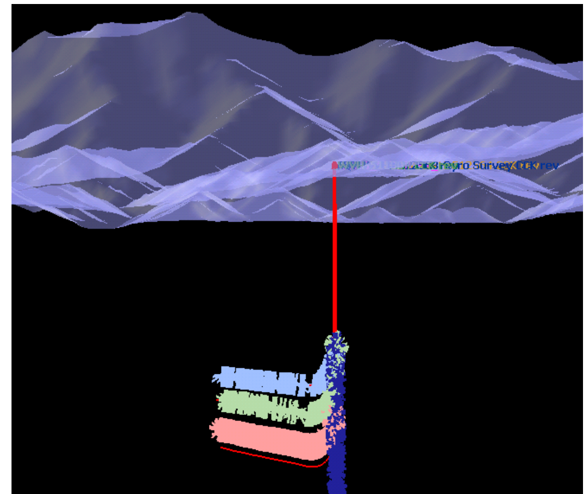
- West Virginia Gas Shale Case History
- Production Behaviors of Simple and Complex Hydraulic Fractures
- Fracture Complexity and EGS
- Oak Ridge Example for Contemplation

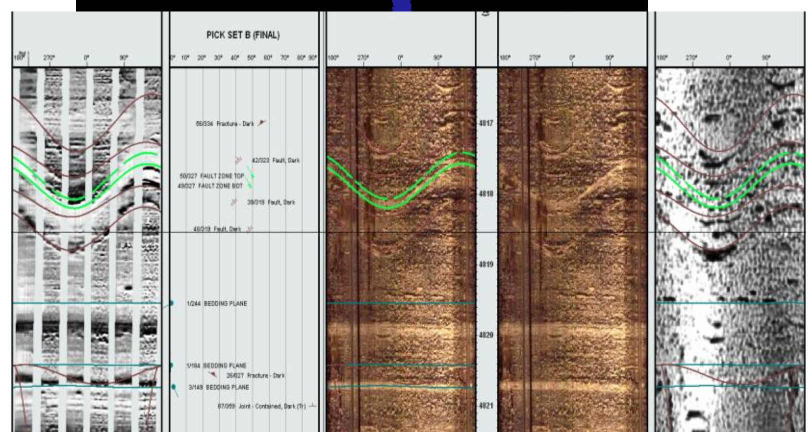


West Virginia Gas Shale

Eastern Gas Shale Overview

- Air drilling and nitrogen fracturing
- Conventional microseismics
- Image logging
- Flow logging using % natural gas in the drilling returns from quadrupole mass spectrometer
- Tracer testing
- Tomographic Fracture Imaging (TFI)





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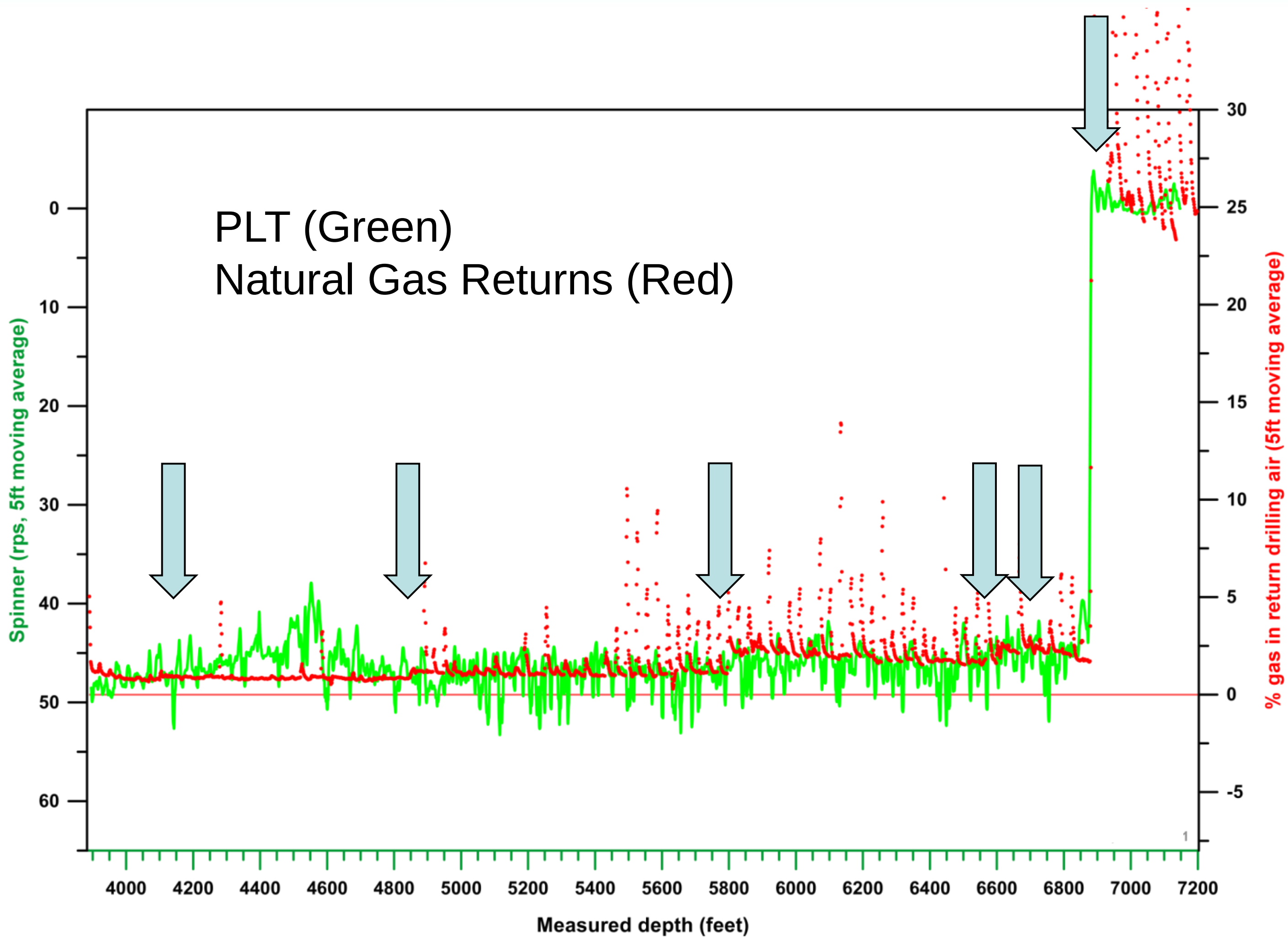
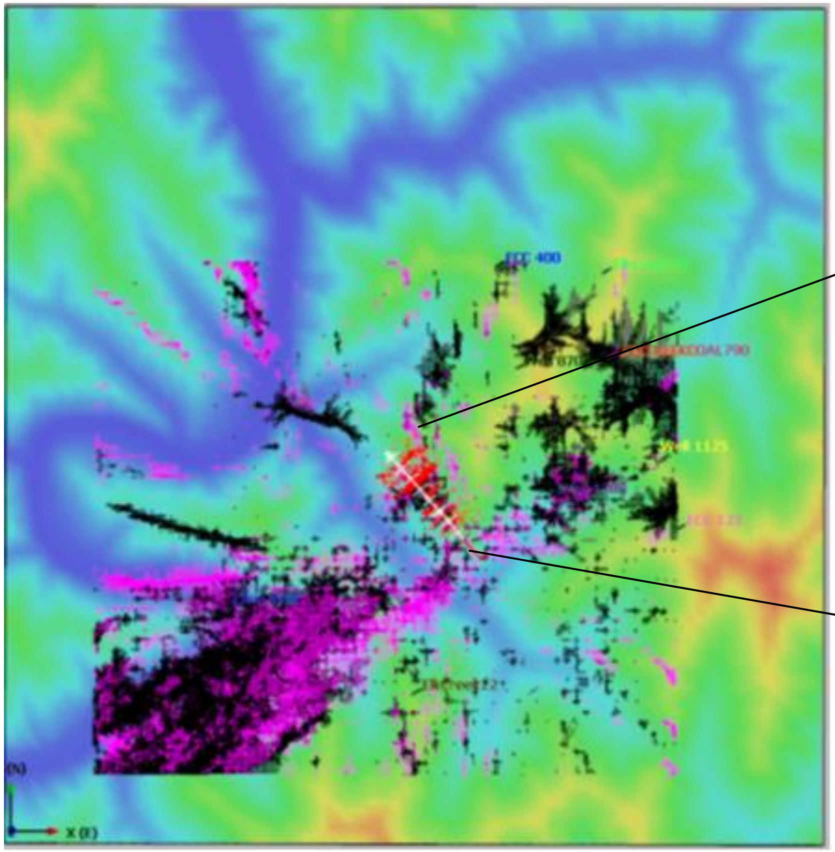
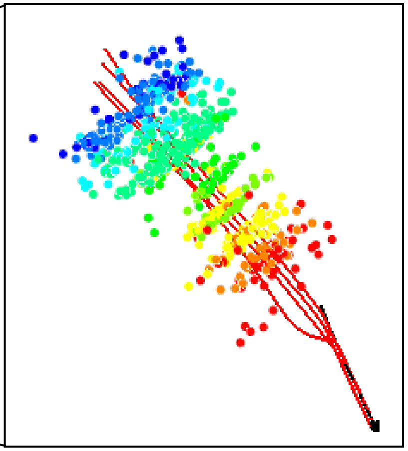
Drilling Gas Monitoring and Production Log



TFI™ Shows Affected Volume Larger than That Shown by Conventional Microseismics



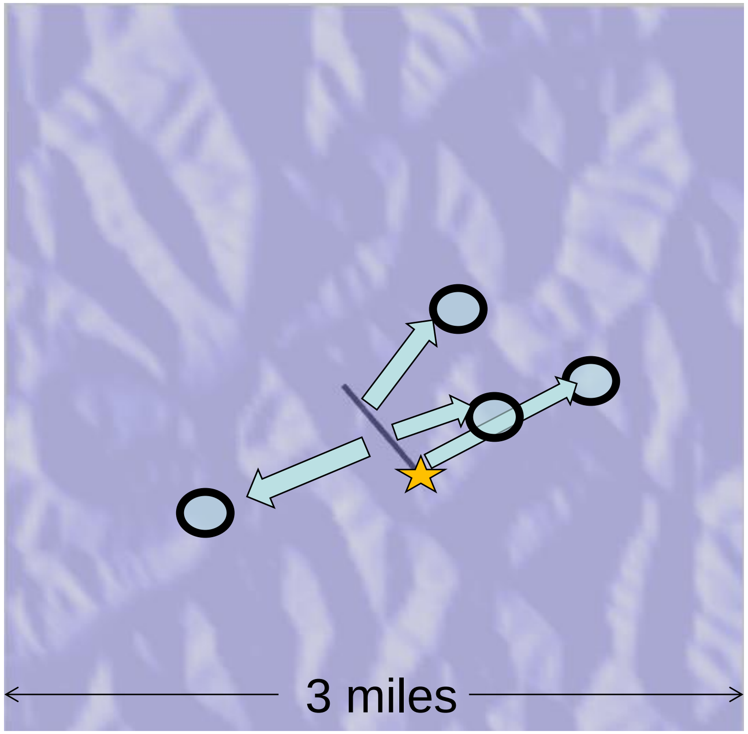
Conventional Microseismics



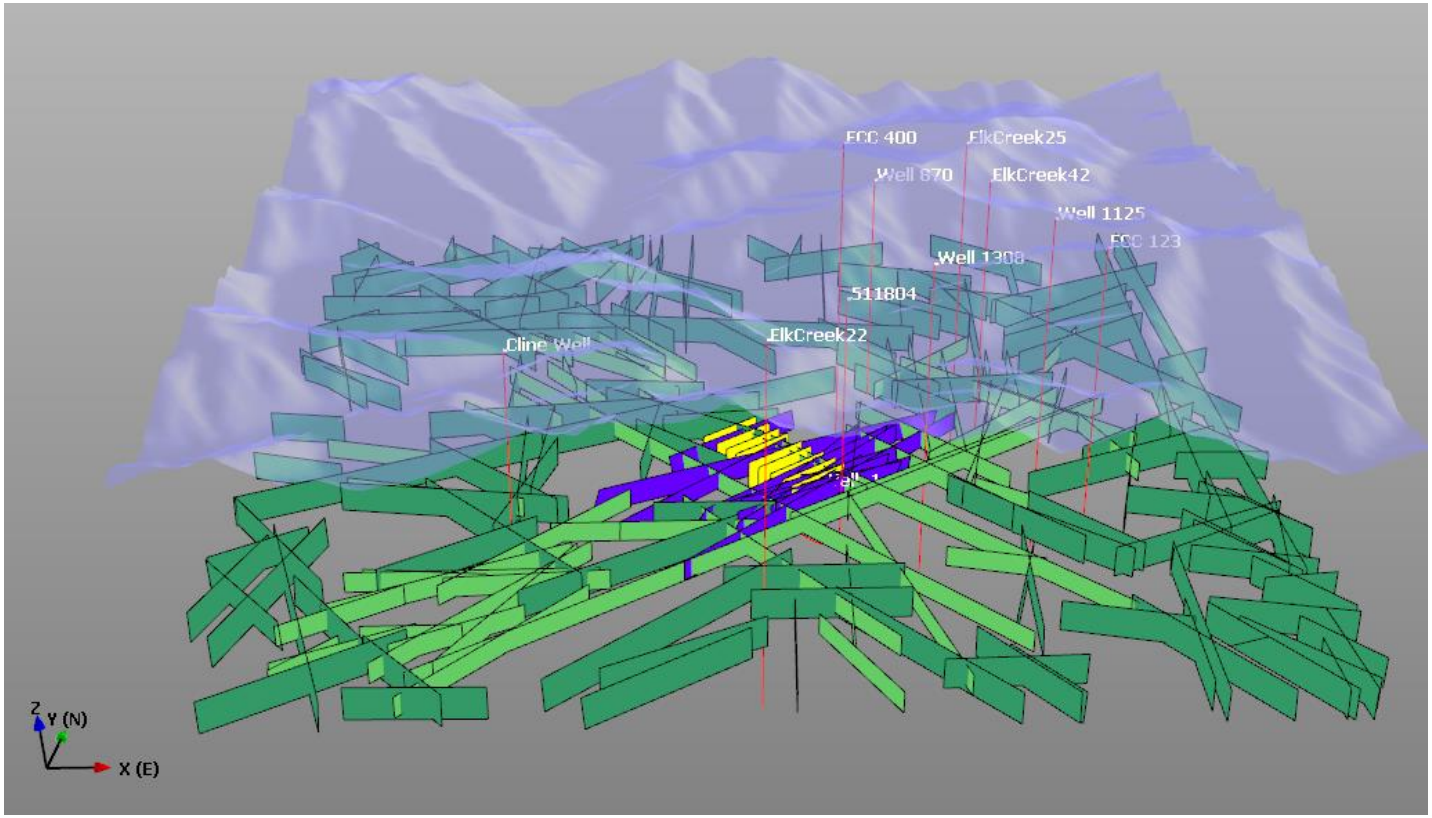
3 miles

Tomographic Fracture Imaging (TFI™) Global Geophysical Inc.

Tracer Responses



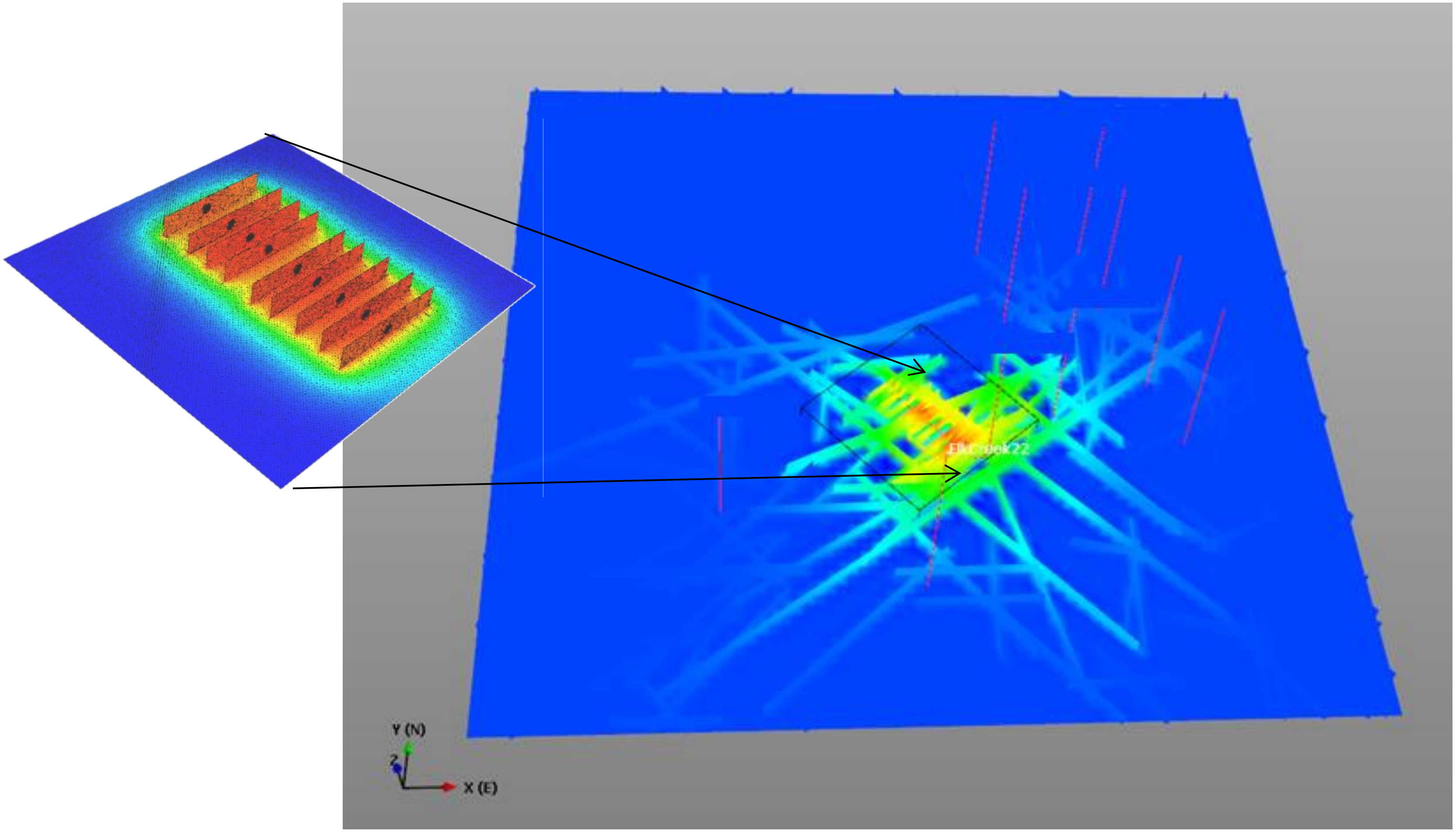
Discrete Fracture Network Model



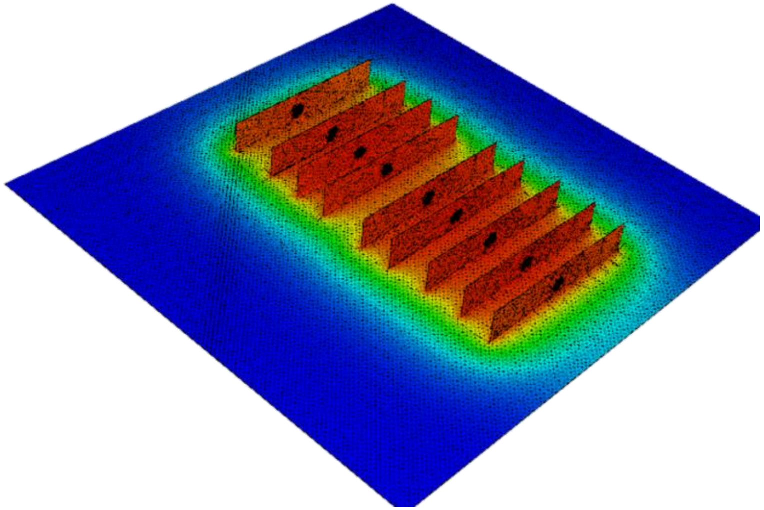
- Hydrofracs
- Conductive Fractures in Well
- TFI Lineaments
- Stochastic TFI Lineaments

3 miles

Pressure From Production

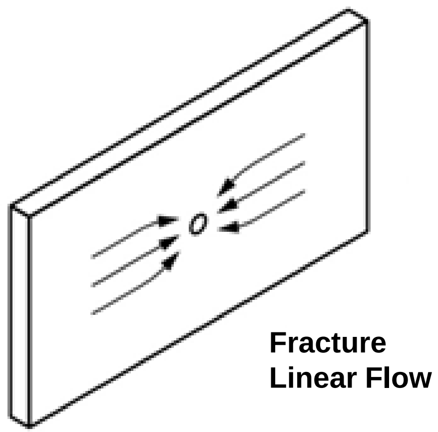


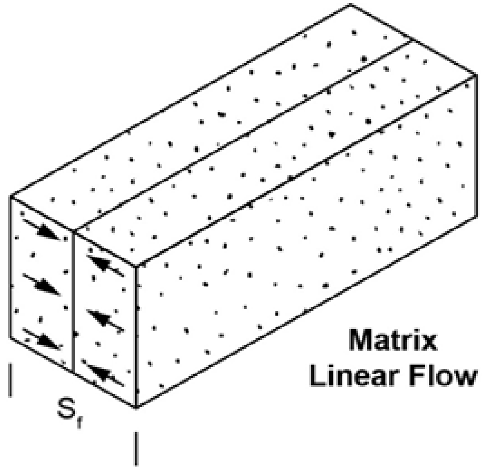
10^8 second ~ 1100 days

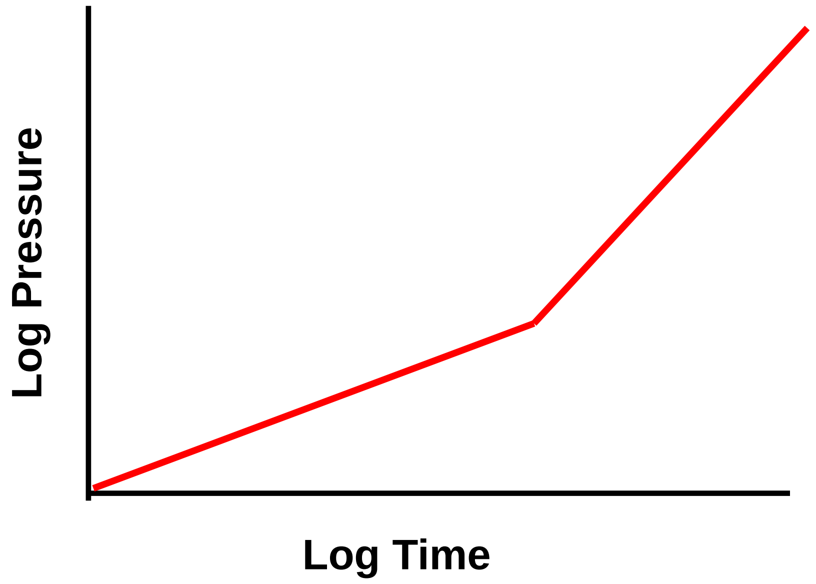


Production from Simple Hydraulic Fractures

Linear Flow (Geometric)







Linear Flow:

Parallel flow lines

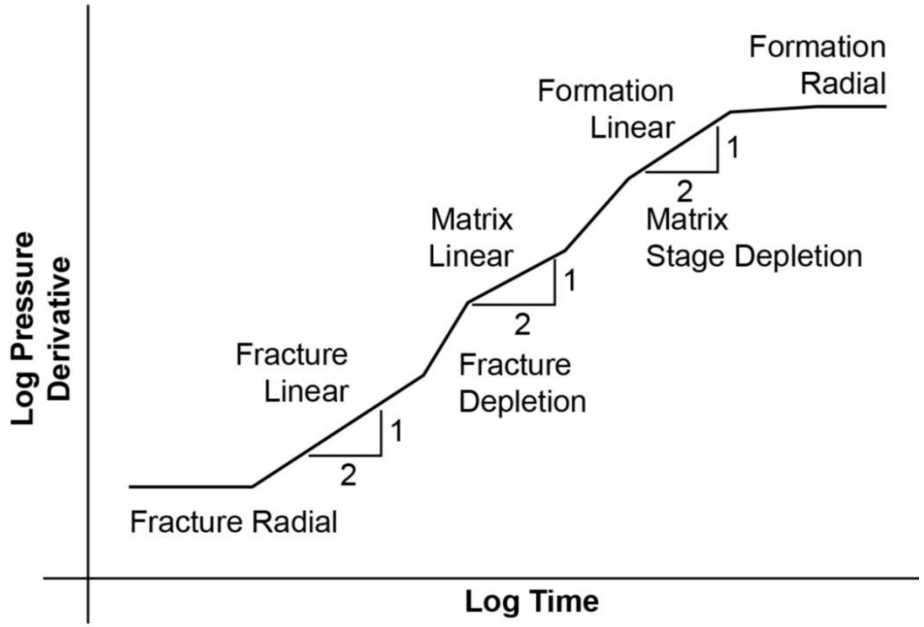
Pressure square-root with time

Depletion:

Producing from closed system

Pressure linear with time

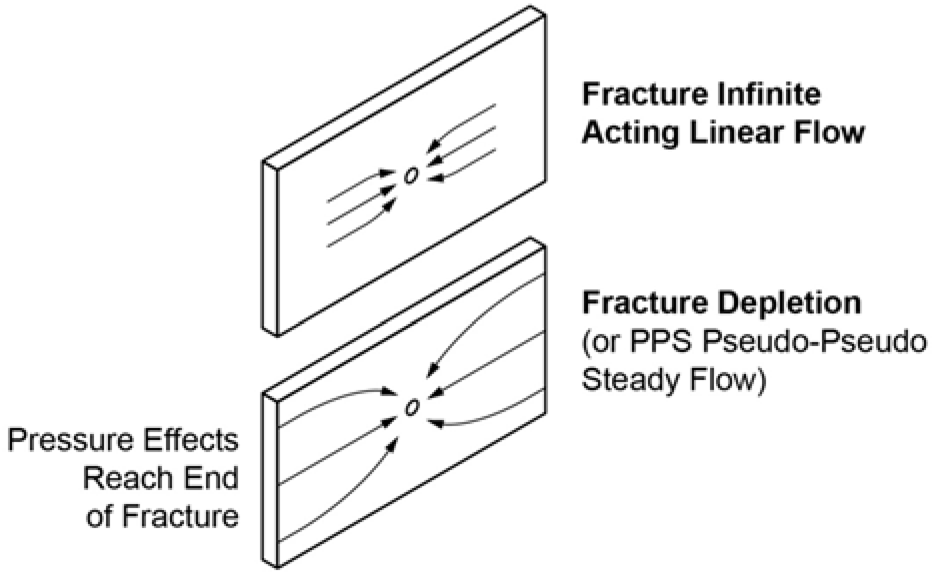
Tri-Linear Flow Regimes

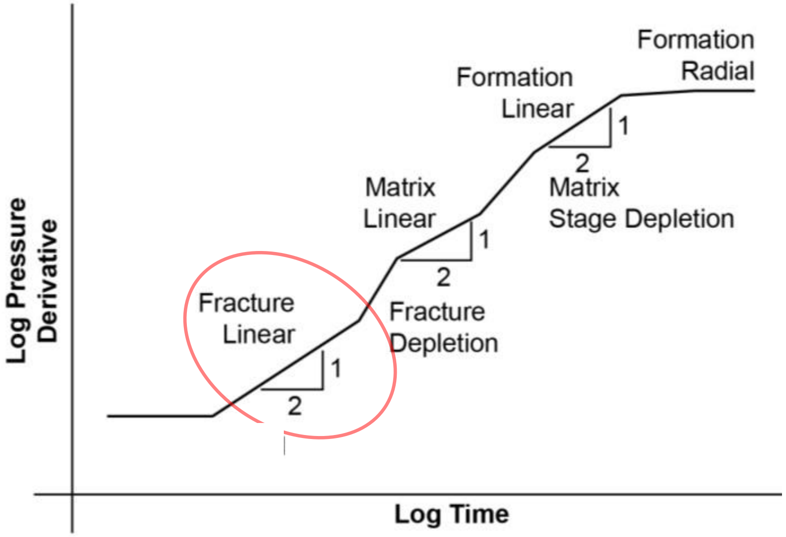


Half-slope linear flow regimes separated by restricted-flow boundary transitions

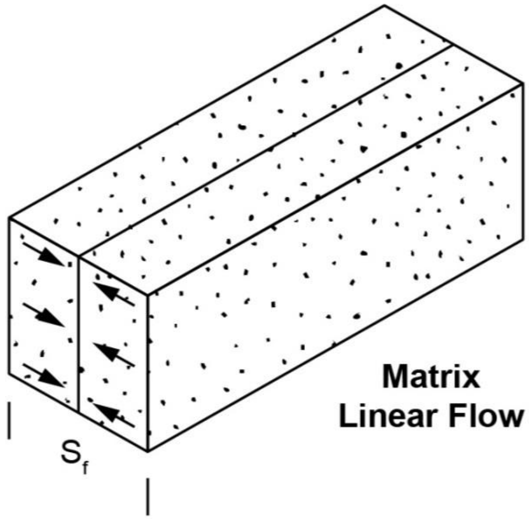
Ozkan E., M. Brown, R. Raghavan, and H. Kazemi, 2011, Comparison of fractured horizontal well performance in tight sand and shale reservoirs. SPE Reservoir Evaluation & Engineering, SPE-121290
Song, B., and C. Ehlig-Economides, 2011, Rate-normalized pressure analysis for determination of shale gas well performance. SPE 144031

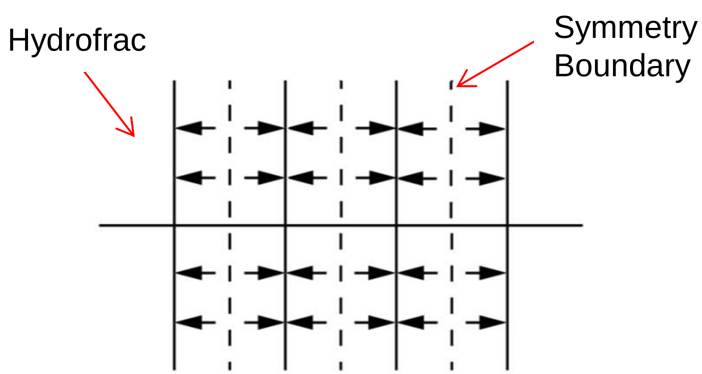
Tri-linear Flow I: Fracture Linear Flow



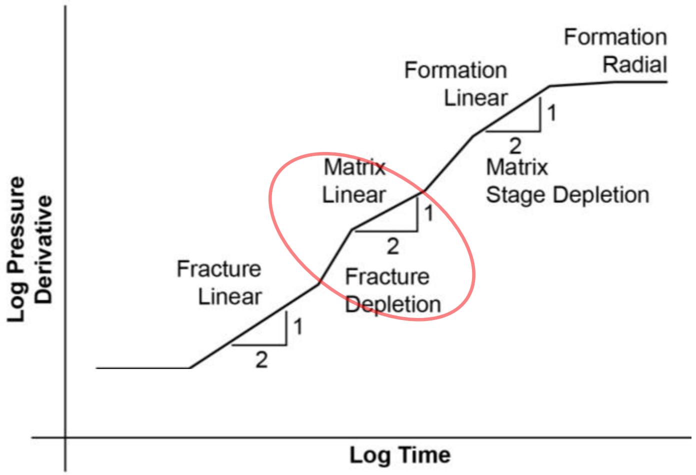


Tri-Linear Flow II: Matrix Linear Flow

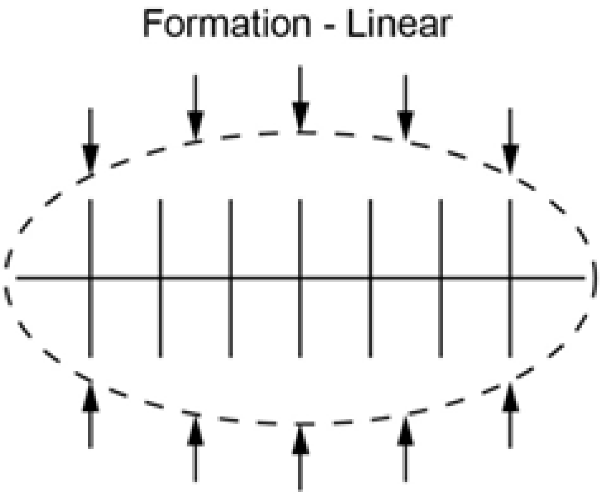


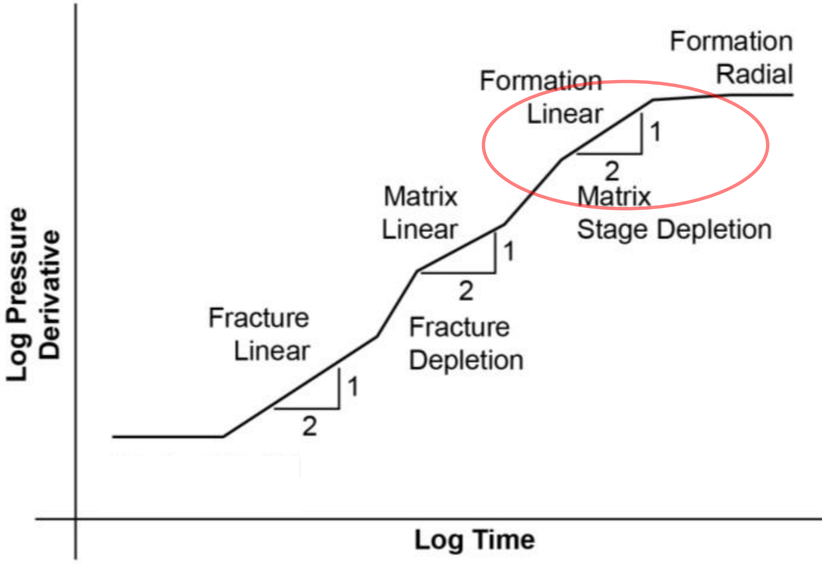


Matrix Depletion

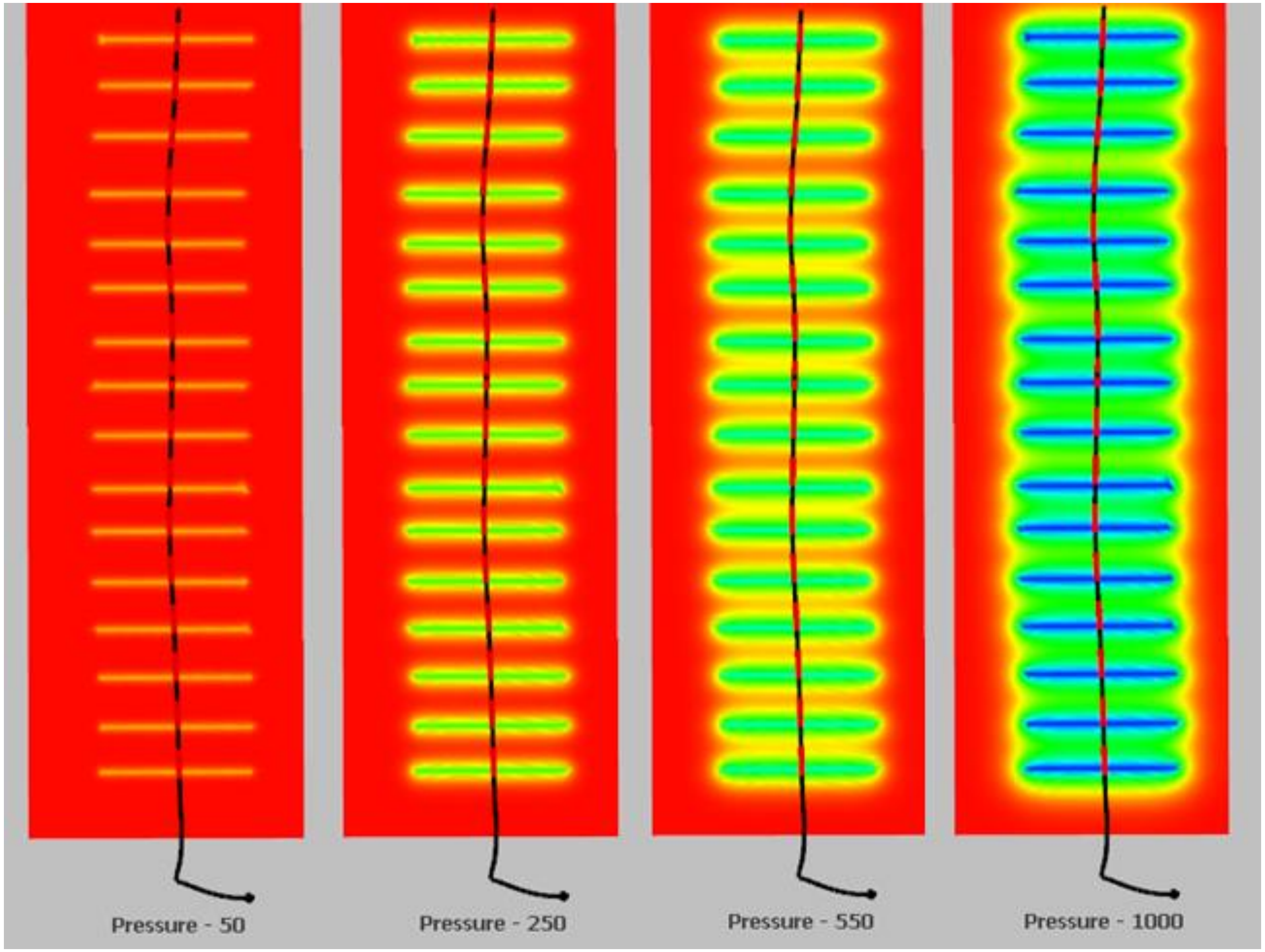


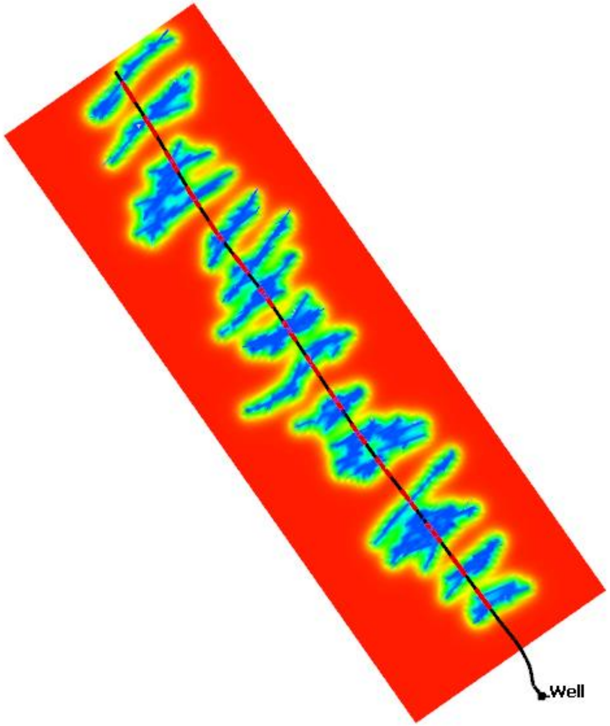
Tri-Linear III: Formation Linear and Radial Flow





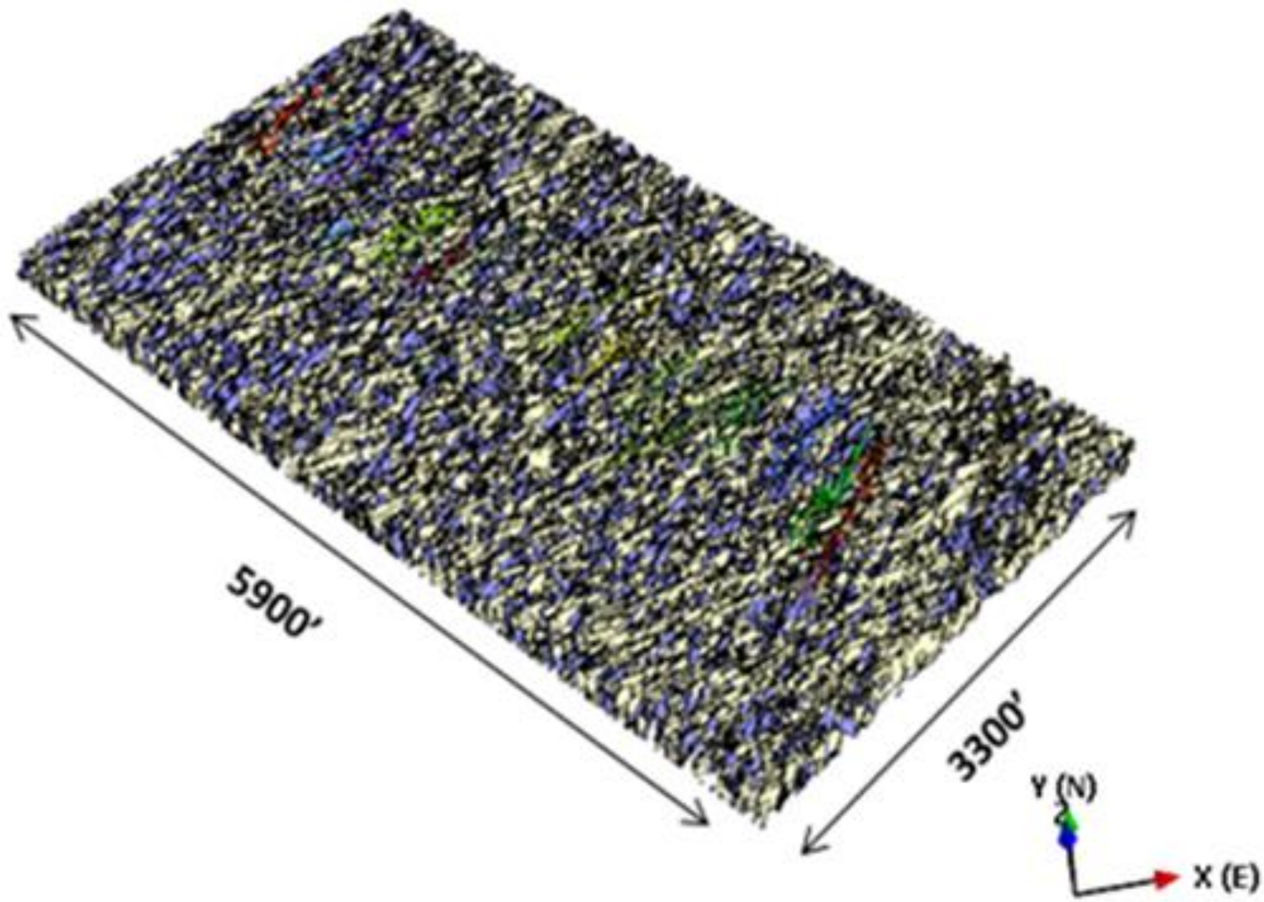
Simple Single Hydraulic Fractures



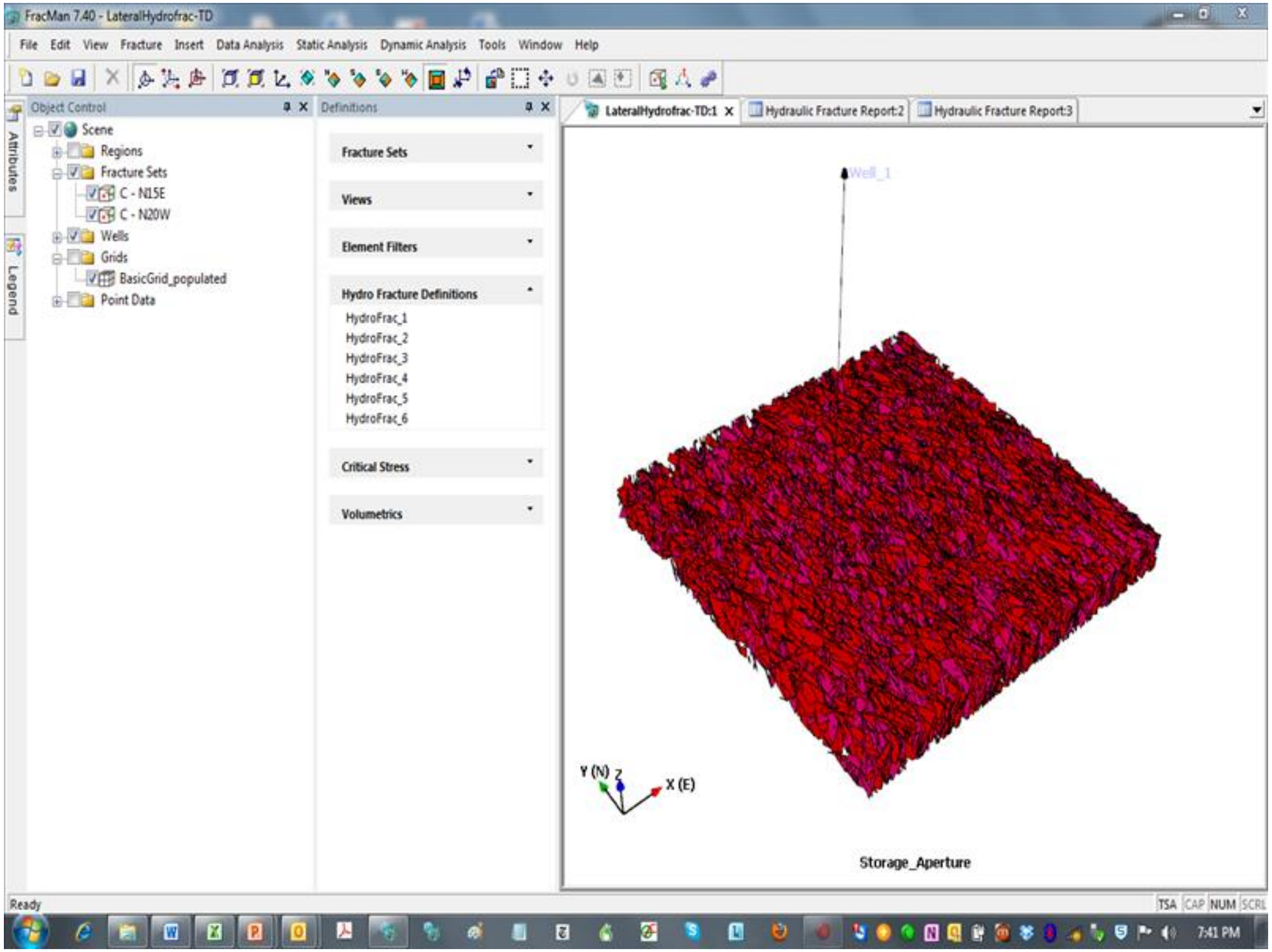


Production from Complex Hydraulic Fractures

DFN Stimulation Simulation



Hydrofrac Generation



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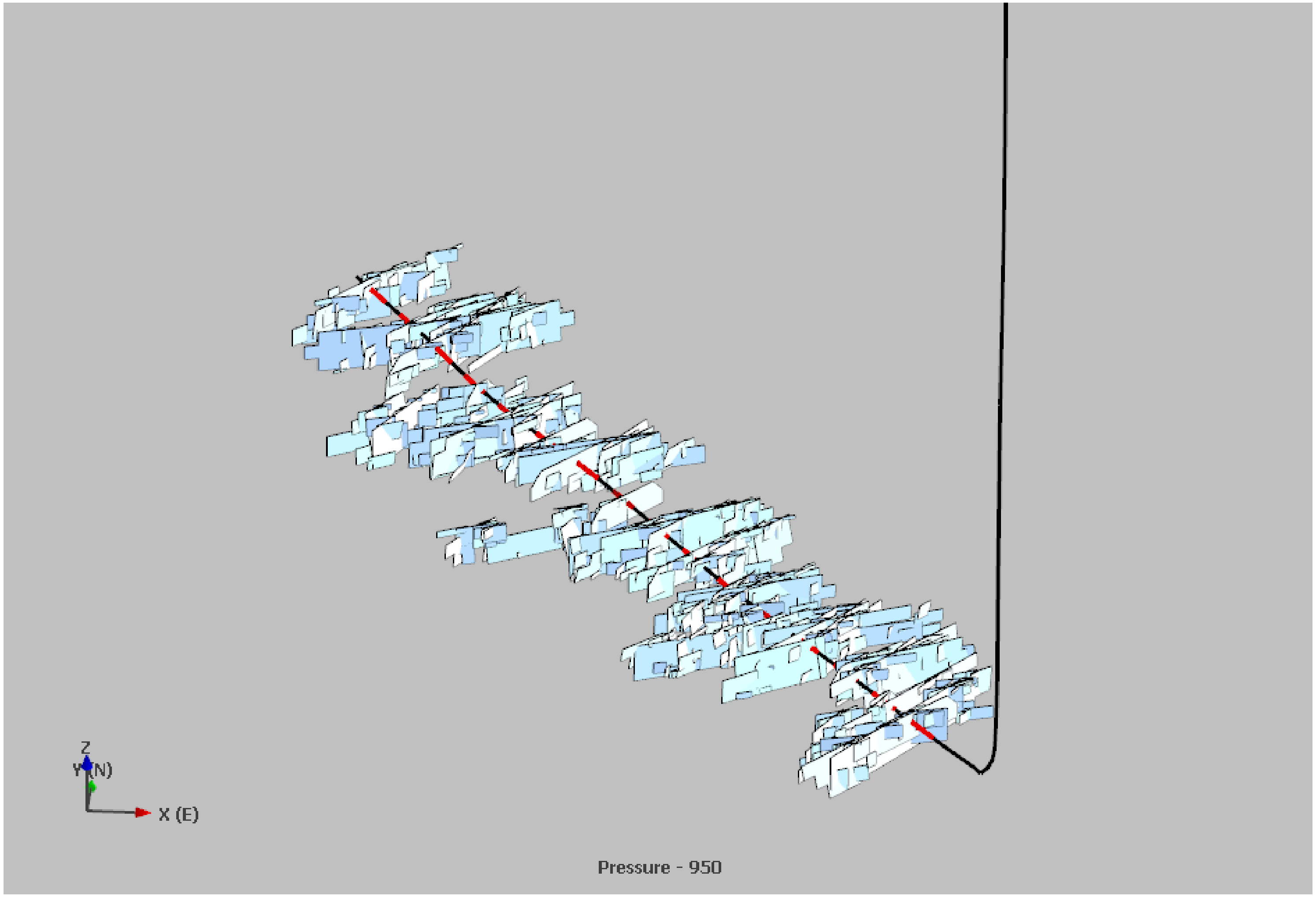
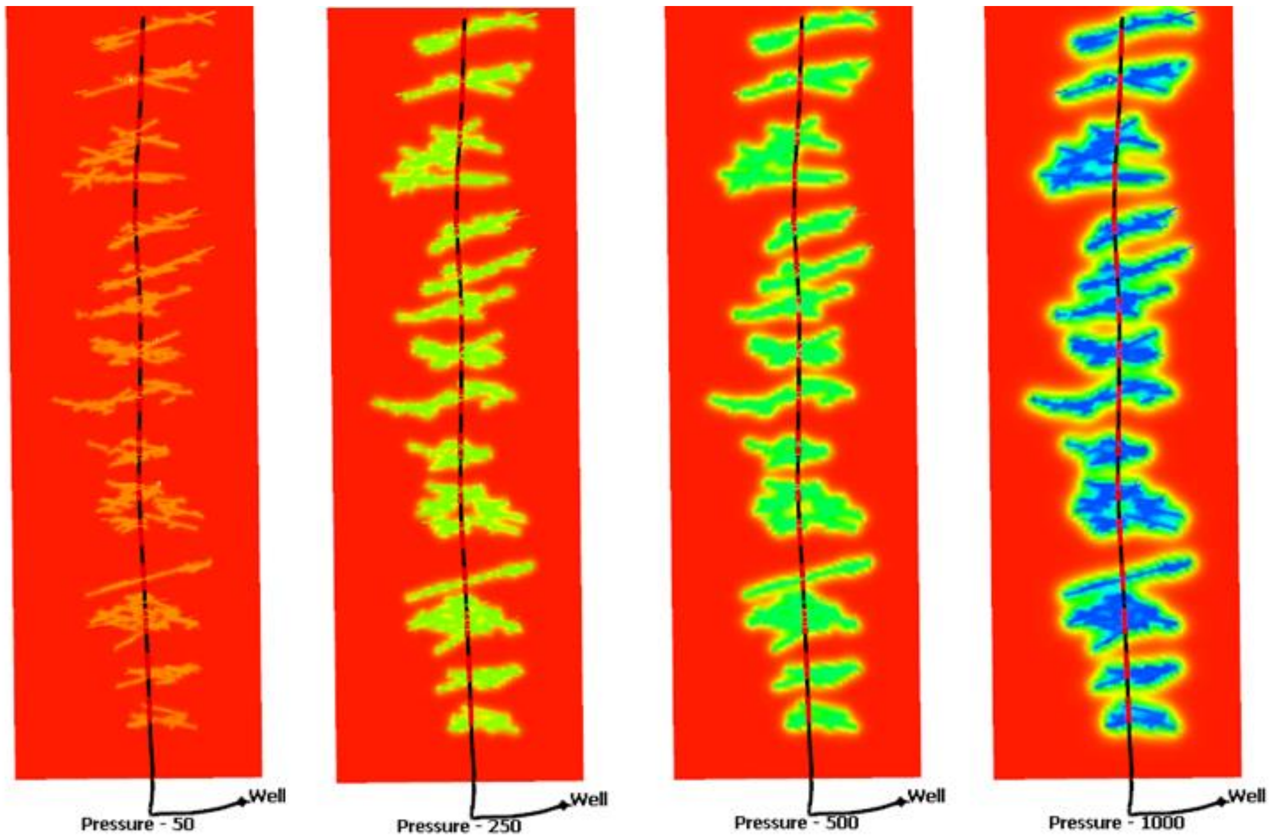
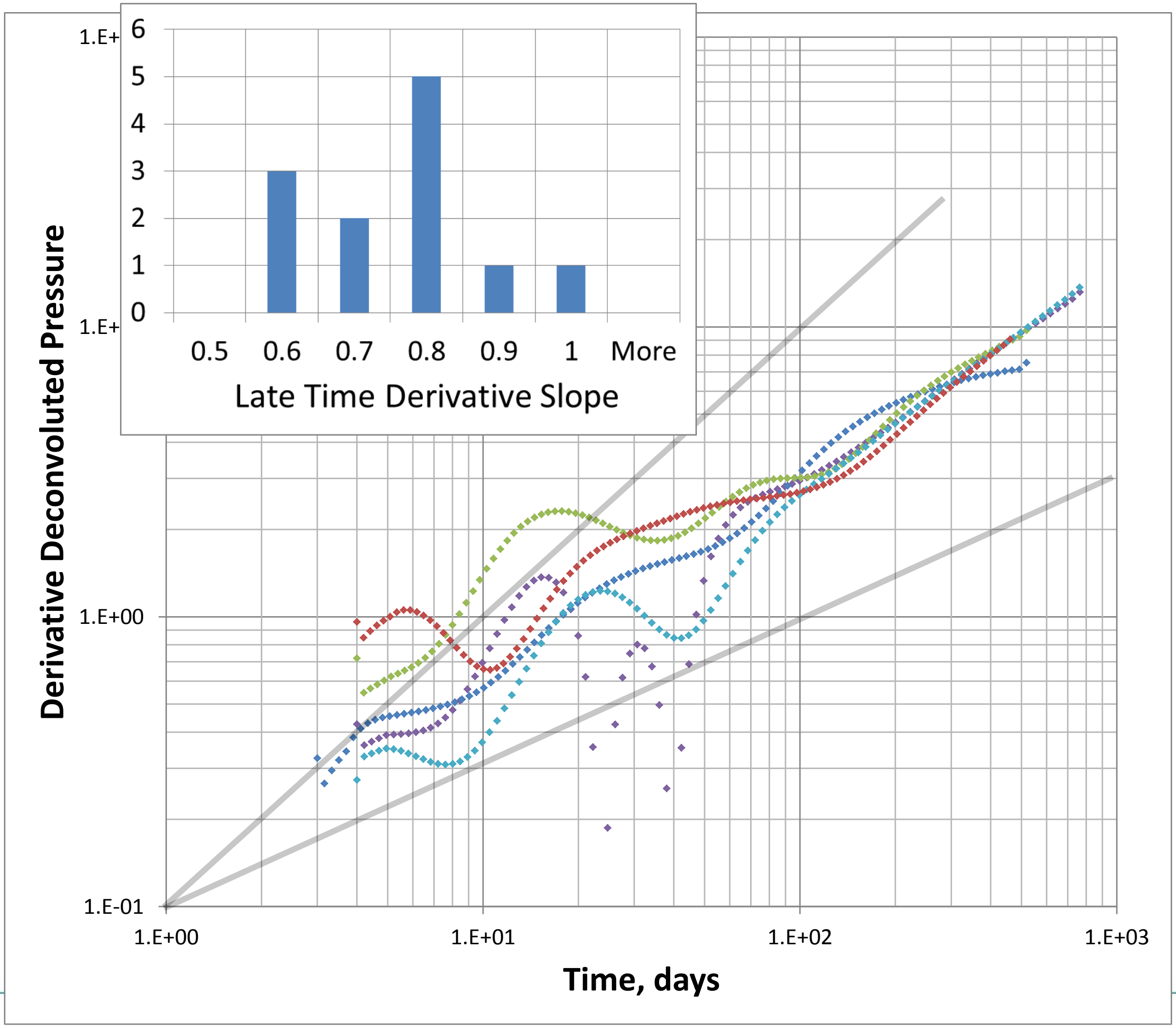
Hydraulic Fractures Generated from Discrete Fracture Network Models



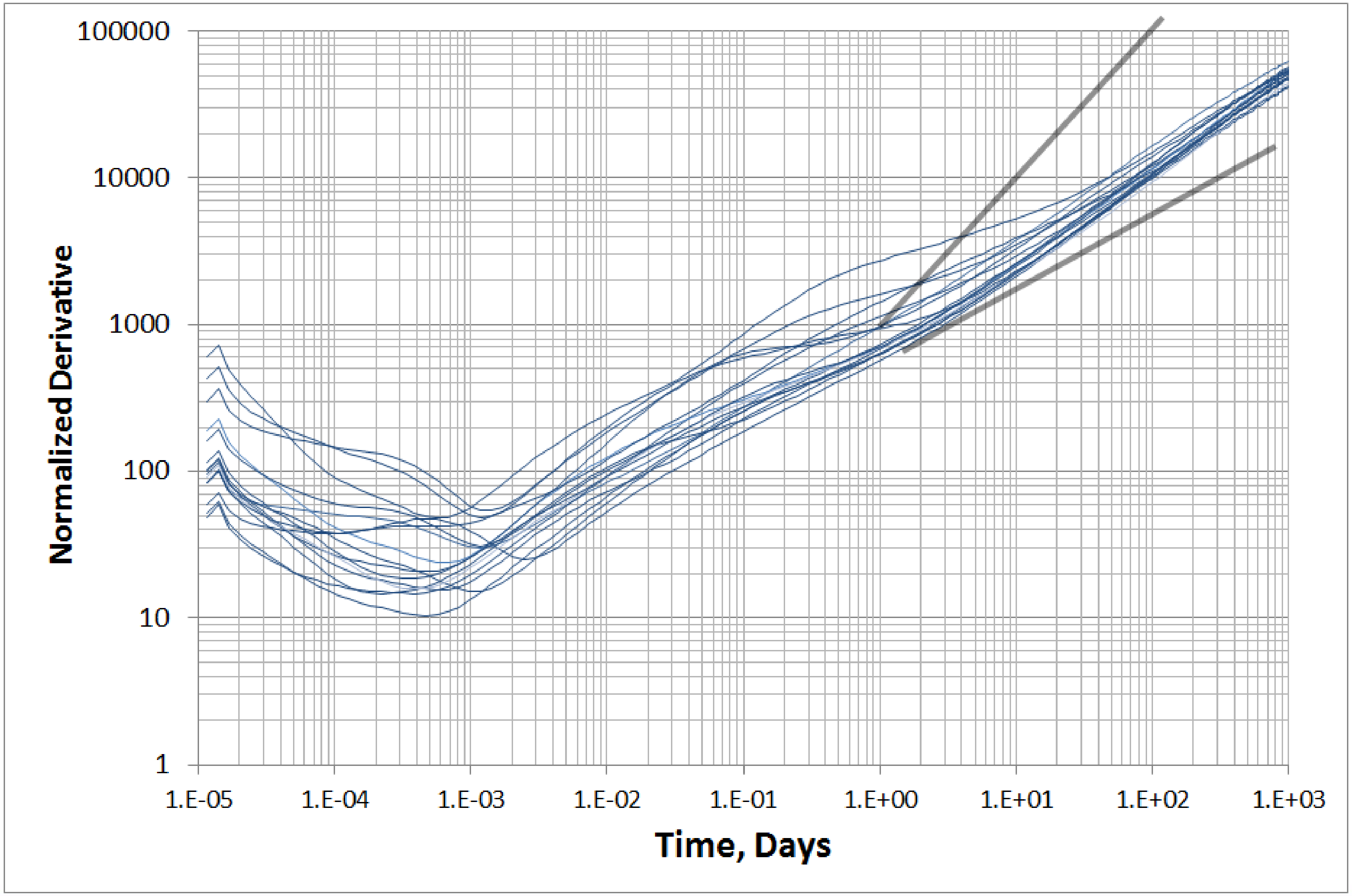
Pressure Drawdown in Complex Networks



Deconvoluted Production Data

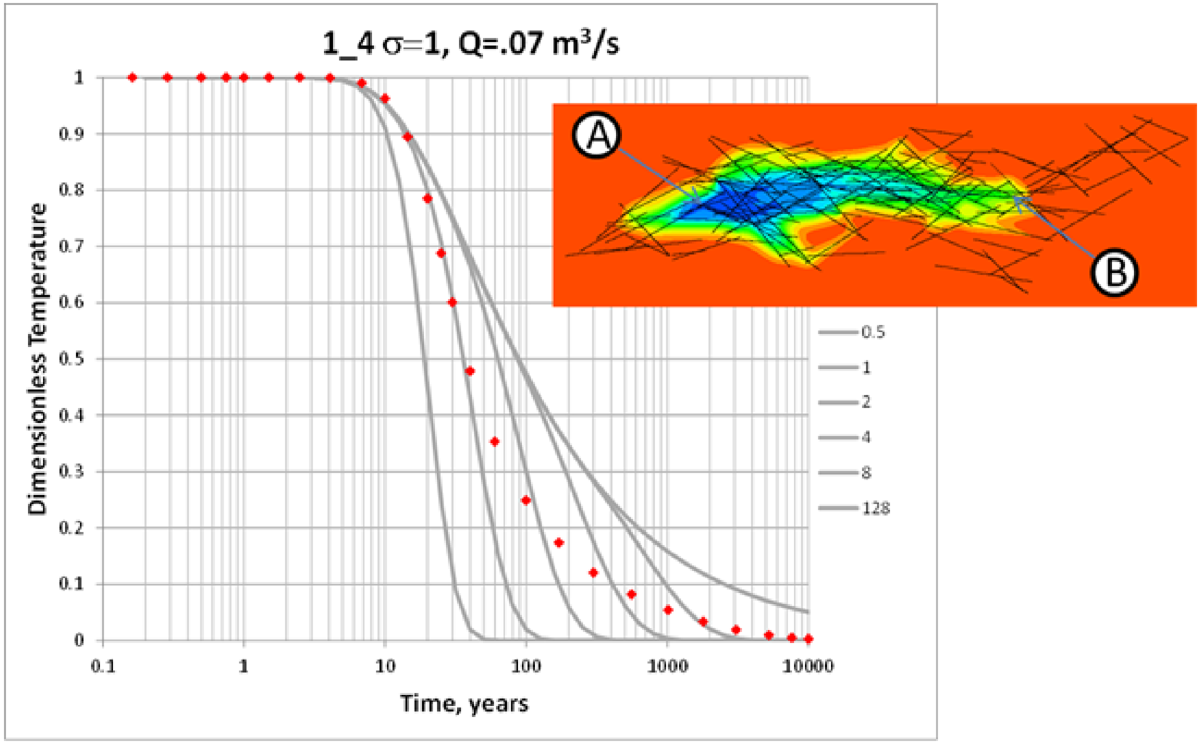


Simulated Derivatives, Complex Fractures



Production Conclusions

- Equal-spaced fractures of equal size
  - Tri-linear flow
  - Linear (half-slope) and Depletion (unit-slope) behaviors for the hydrofracs, matrix, and entire stimulated volume
- Realistic hydraulic fractures involved networks of both hydraulic fractures and stimulated natural fractures
  - Matrix block sizes are variable which obscures transitions from fracture to matrix flow
  - Derivative slopes between a half and one



Geothermal Energy from Complex Fractures

Analytical Solutions – Fluid Flow and Heat Conduction

VOL. 80, NO. 8 JOURNAL OF GEOPHYSICAL RESEARCH MARCH 10, 1975

Theory of Heat Extraction From Fractured Hot Dry Rock

A. C. GRINGARTEN

Bureau Recherches Géologique et Minères, Service Géologique National, Orléans Cedex, France

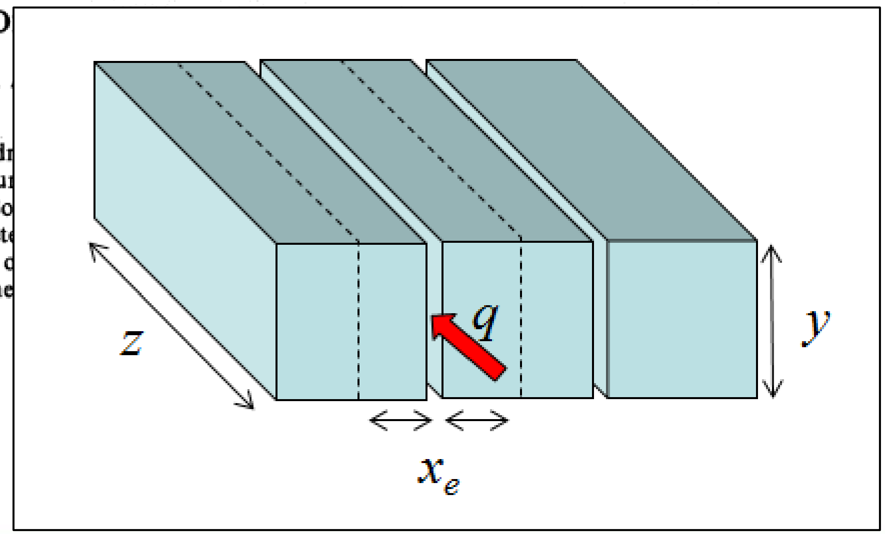
P. A. WITHERSPOON

Department of Civil Engineering, University of California, Berkeley, California 94720

YUZO O

Department of Civil Engineering,

A theory of heat extraction from fractured hot dr
parallel vertical fractures of uniform aperture. Fractu
of homogeneous and isotropic impermeable rock. Co
solutions are given in terms of dimensionless paramet
top of the fractures can be determined. An example c
multiply fractured system provides a more efficient me
hot dry rock.



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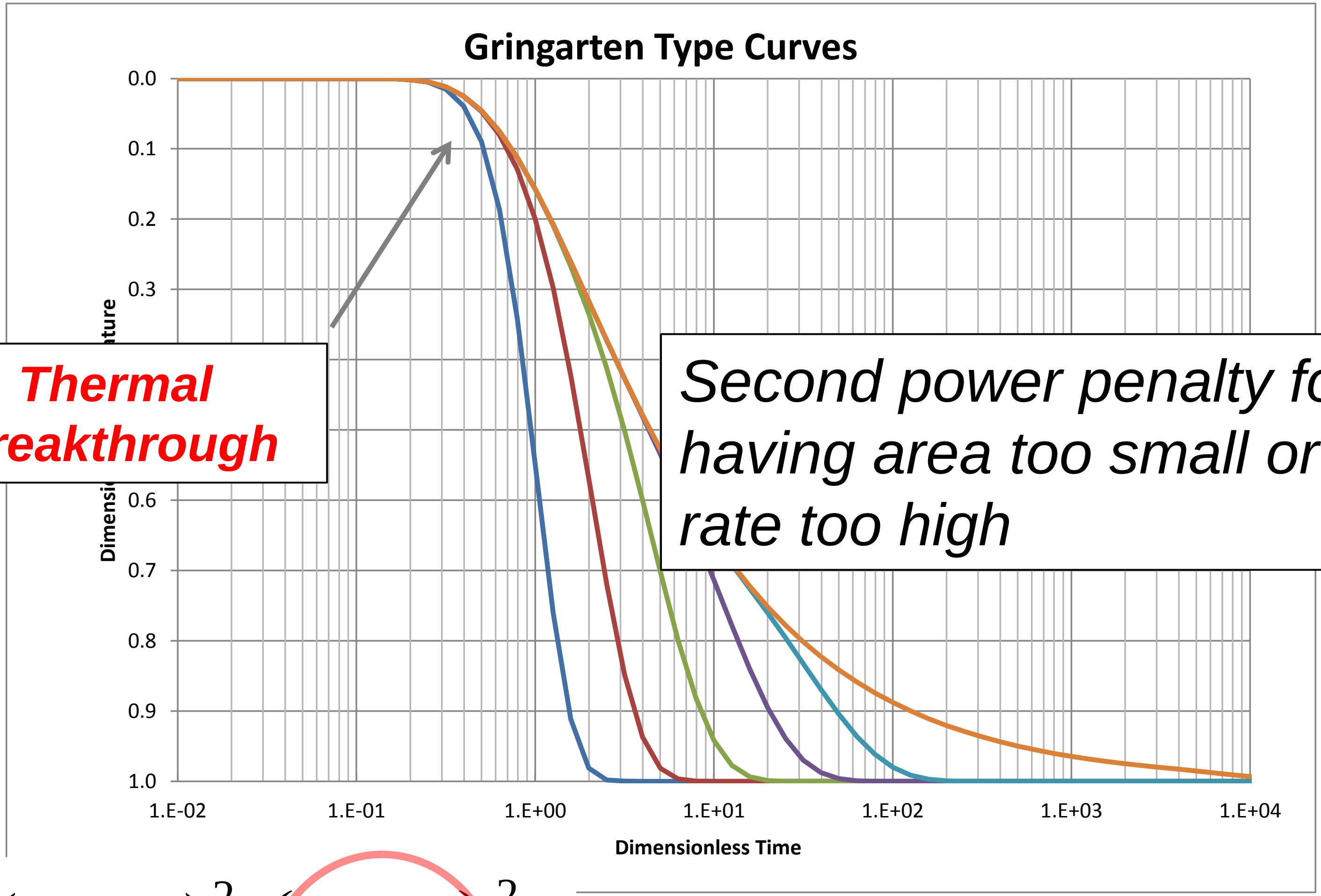
EGS Type Curves

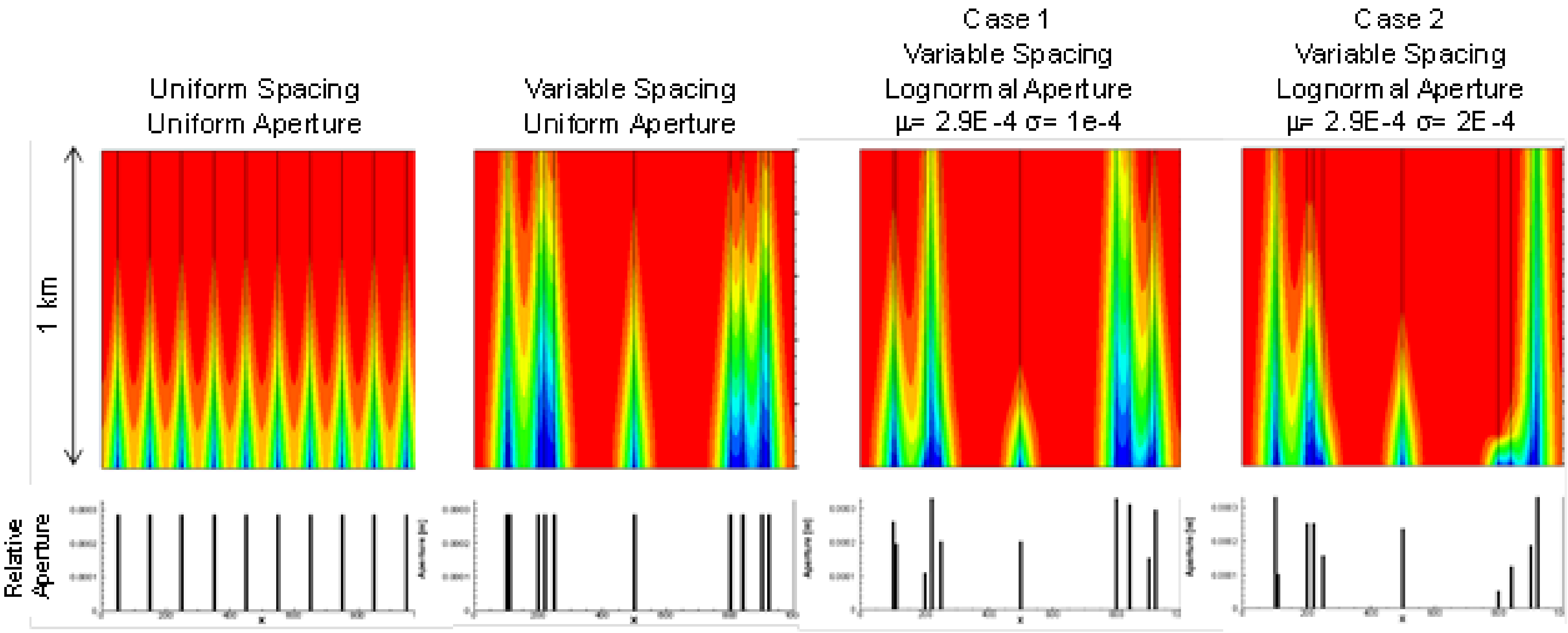


Thermal Breakthrough

Second power penalty for having area too small or rate too high

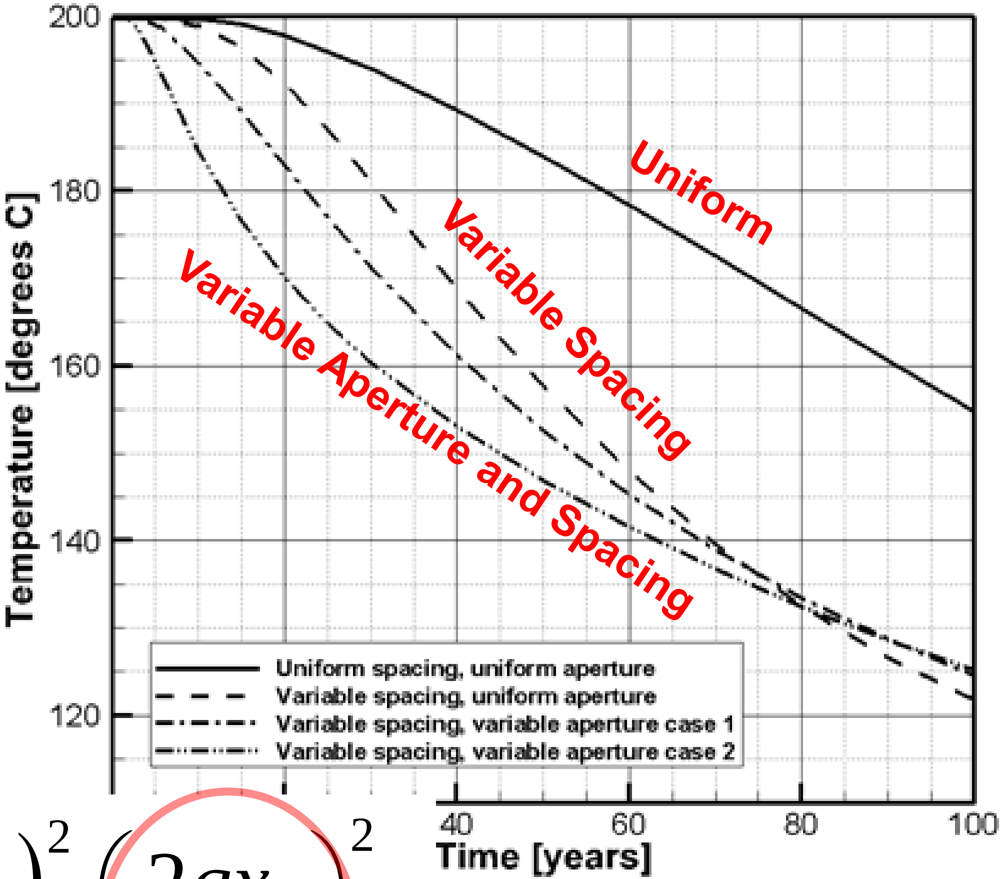
$$t_D = \frac{(\rho_w c_w)^2}{K_R \rho_R c_R} \left(\frac{2qx_e}{xyz} \right)^2 t$$

Variable Spacing – Variable Aperture



Thermal-Hydraulic Calculations: Hydrogeosphere

Thermal Results – Variable Spacing and Aperture



More Heterogeneity, Earlier Thermal Breakthrough

$$t_D = \frac{(\rho_w c_w)^2}{K_R \rho_R c_R} \left(\frac{2qx_e}{xyz} \right)^2 t$$

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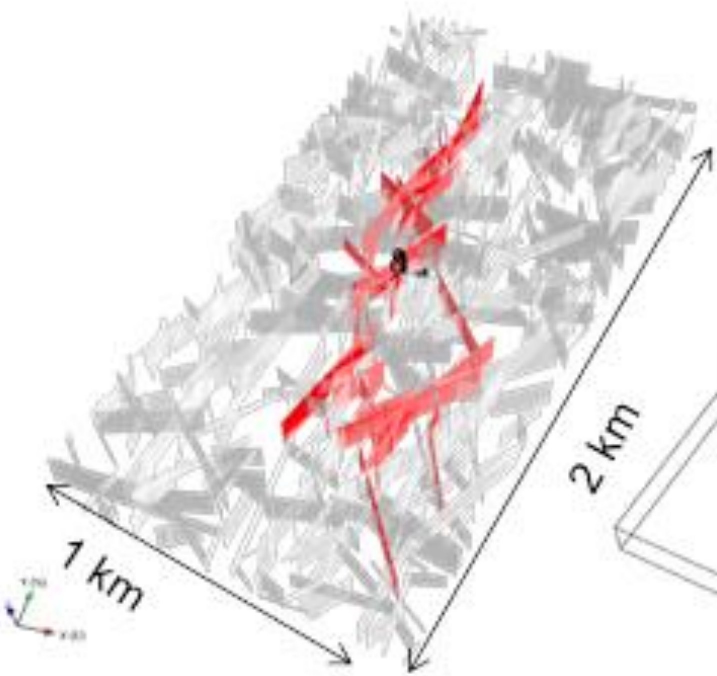
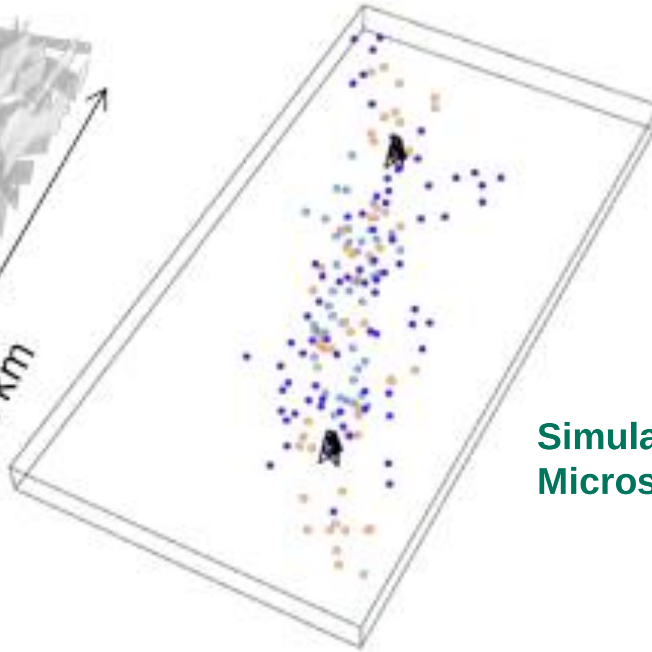
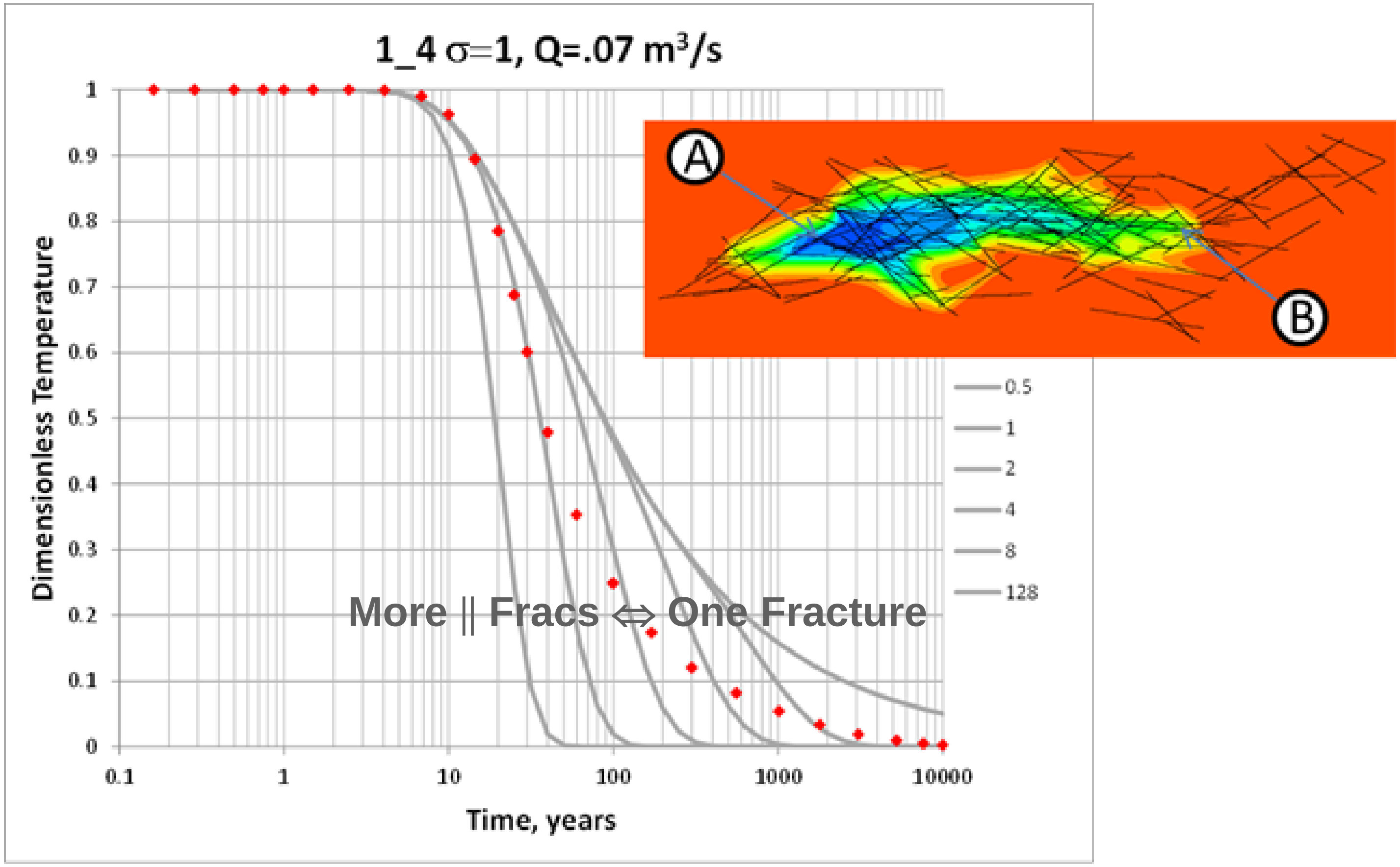
FracMan Fractures and Stimulated Network





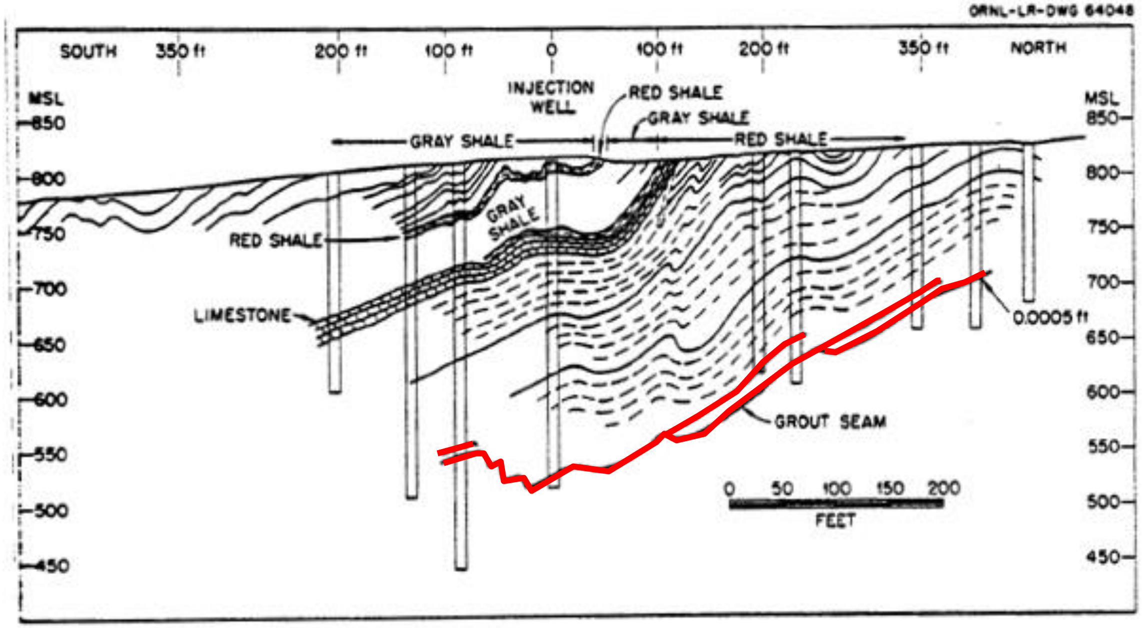
Simulated Microseismics

Thermal Performance – Realistic Network



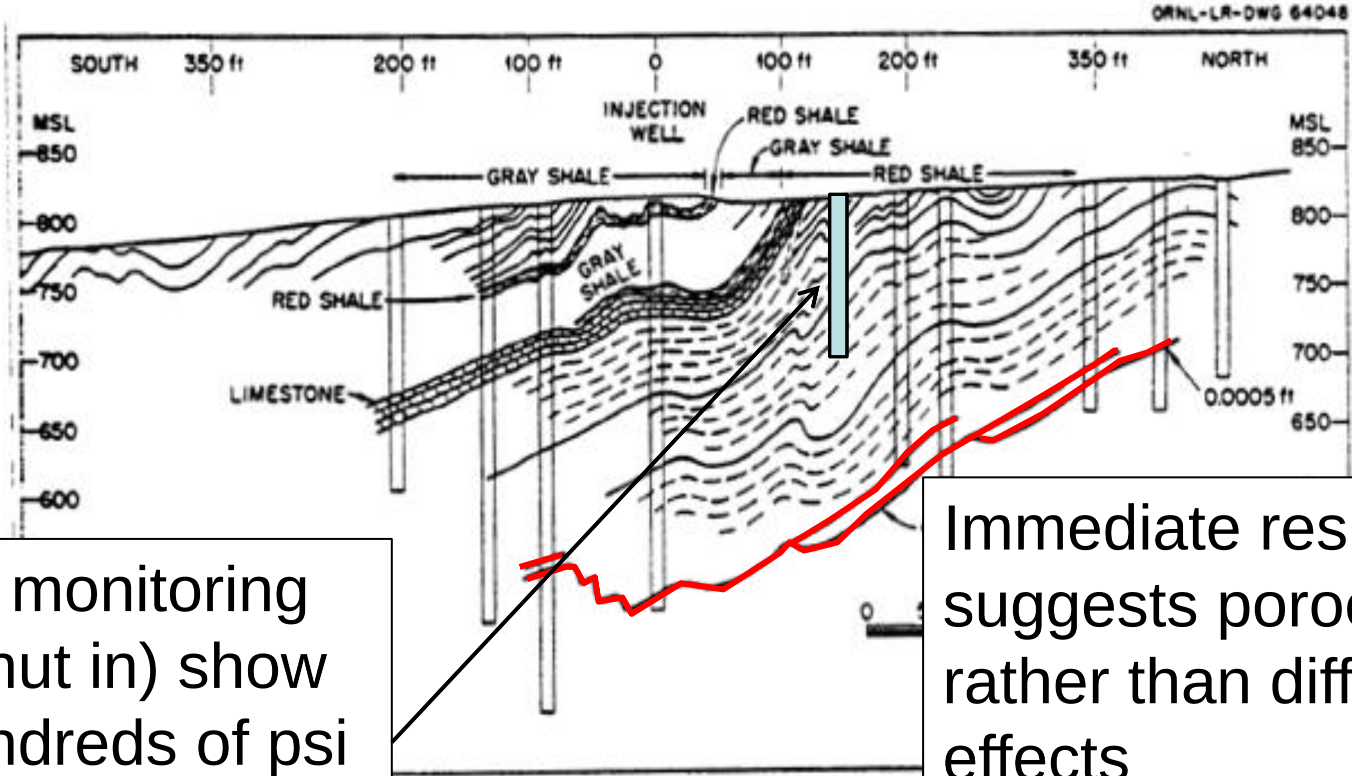
Oak Ridge Hydraulic Fracturing (1963-1984)

- Liquid radioactive wastes in “old” and “new” facility
- 13 injections of about 200,000 gal each
- Slurry designed to solidify and chemically retain radionuclides



S.H. Stowe and C.S. Haase, 1986, Subsurface disposal of liquid radioactive waste at Oak Ridge, Tennessee, Proceedings of the International Symposium of Subsurface Injection of Liquid Wastes, New Orleans, p. 656-675, National Water Well Association

Elevated Pressure in Shallow Monitoring Wells



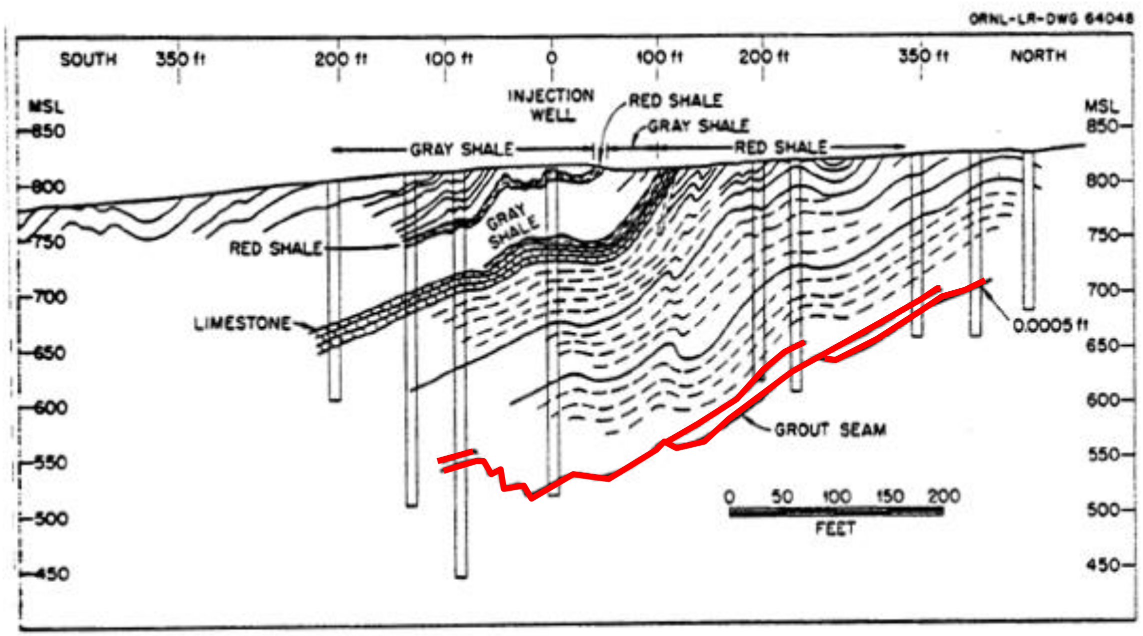
Shallow monitoring wells (shut in) show tens-hundreds of psi immediate buildup during injections

Immediate response suggests poroelastic rather than diffusive effects

S.H. Stowe and C.S. Haase, 1986, Subsurface disposal of liquid radioactive waste at Oak Ridge, Tennessee, Proceedings of the International Symposium of Subsurface Injection of Liquid Wastes, New Orleans, p. 656-675, National Water Well Association

End of Disposal Operation

- Discovery of radioactive contamination about 1000' from site (where it was not expected)
  - Low concentration (2-4 μCuries/l vs vs 76 mCuries/l in the waste
  - No appearance at surface or in water wells
  - Confined to shale
  - But still not expected
- DOE decided in 1986 not to seek a license
- Area subject to remediation efforts



S.H. Stowe and C.S. Haase, 1986, Subsurface disposal of liquid radioactive waste at Oak Ridge, Tennessee, Proceedings of the International Symposium of Subsurface Injection of Liquid Wastes, New Orleans, p. 656-675, National Water Well Association

Take Home Thoughts

- Natural fractures introduce significant variability that is not accounted for in simple conceptualizations
- Important variability is in block size for controlling fracture-matrix interaction
  - *Unconventionals*
  - *Conventional Type-II Reservoirs*
  - *Contaminant Transport*
  - *EGS*
  - *Radioactive Waste*
  - *CO2 Sequestration*
- There is much we need to understand about these issues especially if we are develop resources wisely and sustainably

Spindletop, 1900's

"We milked the cow too hard. Moreover she was not milked too intelligently."

Captain Anthony Lucas, 1905

Discoverer and developer of the Spindletop field, East Texas

Quoted by Daniel Yergin, The Prize, Simon and Schuster. 1991